Asparagus waste streams to aroma-rich vegetable flavourings (The effect of partial replacement of maltodextrin with vegetable fibres in spray-dried white asparagus on its aroma properties)

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Abstract

White asparagus (*A. officinalis*) is a popular vegetable consumed worldwide and its cooked spears are appreciated for their distinct flavour profile. During asparagus harvesting, around one-third of the total material is usually discarded. This significant waste stream partially consists of the stem bases which are cut off to produce spears with the same desired length for delivery to the supermarket. This waste stream could become a valuable resource of food ingredients. Asparagus waste was used to generate an asparagus concentrate, and this was spray-dried in different carrier formulations in which maltodextrin was partially replaced by cellulose-based carriers, i.e. asparagus fibre, citrus fibre or microcrystalline cellulose. Powders obtained from feed solutions with an initial solids content of 40 % w/w showed better physical properties and aroma retention than 30 % w/w. Partial replacement of maltodextrin by cellulose-based carriers resulted in powders with similar physical properties to the control and did not detrimentally influence the aroma profiles as analysed by headspace solid-phase microextraction and gas chromatography-mass spectrometry. Aroma analysis was focused on asparagus key volatiles based on previous studies. This research showed that fibre obtained from asparagus waste streams could potentially be used as a carrier to produce spray-dried asparagus powder with retained key asparagus odorants such as 2-methoxy-3-isopropyl pyrazine. Valorisation of these materials could reduce the amount of agricultural waste while generating aroma-rich natural food products.

Keywords: asparagus aroma, volatile retention, GC-MS, asparagus fibre

Introduction

White asparagus (*A. officinalis*) is a globally popular vegetable, of which the cooked spears are appreciated for their distinct flavour profile which is perceived as being slightly more bitter and less sweet than its green counterpart [1]. Vegetables, including asparagus, often have rich aroma profiles which are also influenced by their processing history (e.g. fresh, cooked, dried, etc.). The aroma profile of cooked white asparagus has been studied in the past [2,3], and these studies have indicated its complexity as it consists of volatile compounds from diverse chemical classes, including aldehydes, pyrazines and sulphur compounds (Figure 1).

Asparagus is known for its limited harvest season, which in Europe is between March until June. Unfortunately, after harvest, ca. one third of the collected crop is discarded as waste for the following reasons; the bottom parts are cut off to create spears of the same length and some harvested spears are bent, broken or slightly purple/green-pigmented, and thus do not fit the strict market requirements.

Asparagus waste streams are being used for the production of dry powders as ingredients for soups and sauces in the food industry. However, currently available asparagus powders are considered inferior to the quality of the fresh material in terms of flavour, as the retention of key aroma components is poor. Ideally, the food ingredient industry requires a powder which has the maximum levels of key flavour and fragrance components typifying the freshly – cooked vegetable, and which meets clean-labelling and sustainability requirements without the need for any ‘artificial’ additives. The objective of this study was to evaluate the aroma profile of dried asparagus powders that were produced with the suggested split-stream processing strategy (Figure 2) [4]. This strategy aims for the optimal exploitation of the generated asparagus waste streams to produce a dried powder with the maximum possible retention of key aroma compounds. The aroma profiles of the dried powders were analysed using a headspace solid phase microextraction gas chromatography mass spectrometry method (HS-SPME GC-MS).

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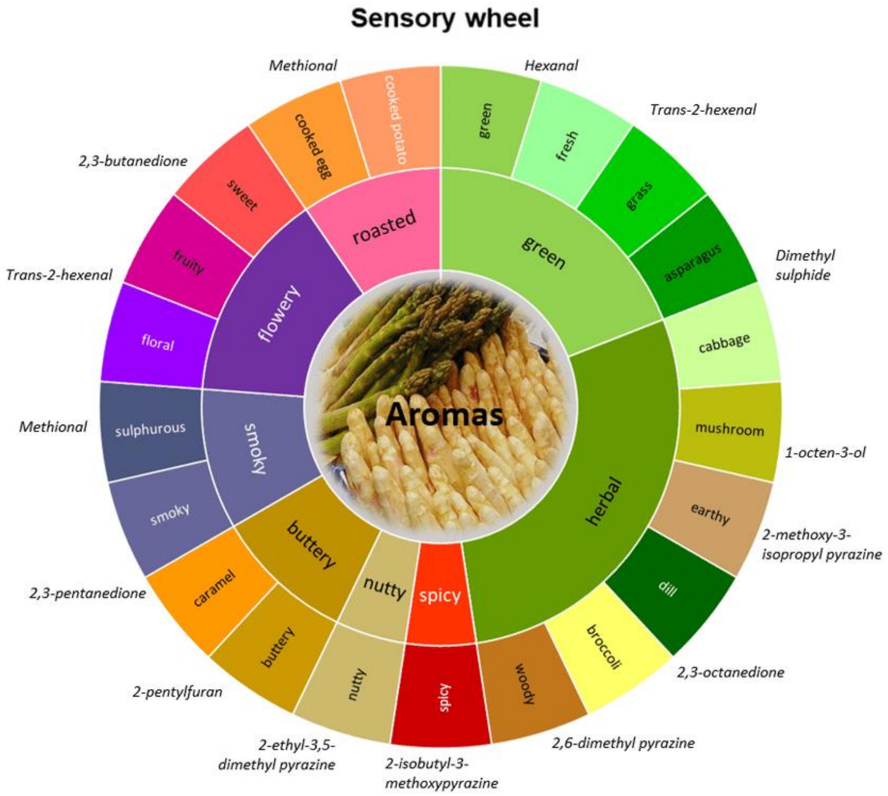

Figure 1*: The Asparagus Sensory Wheel - constructed based on key odorants and sensory attributes from the literature reported in our recent review [1], from which the figure is reproduced with permission.*

Experimental

Spray-dried asparagus powders

Raw, fresh asparagus cut-offs (*A. officinalis*) were kindly provided by Teboza BV (Helden, The Netherlands). Concentrated asparagus juice was prepared from asparagus cut-offs by Wageningen Food & Biobased Research (Wageningen, the Netherlands), as described previously [4]. The generated asparagus concentrate was spray dried, using a Büchi Mini Spray Dryer B-290 (Büchi Labortechnik AG, Flawil, Switzerland), under validated conditions (e.g. inlet temperature, pump speed) [5]. The separated asparagus fibre (AF) was dried and used as a carrier agent for the spray drying of the asparagus concentrate, partially replacing the maltodextrin (MD), which is a commonly used spray drying carrier agent, and it has been shown to contribute in the successful spray drying of asparagus concentrate [5]. Different concentrations of the carrier agents were also tested. All spray-dried asparagus powders were produced following the split-stream strategy (Figure 2).

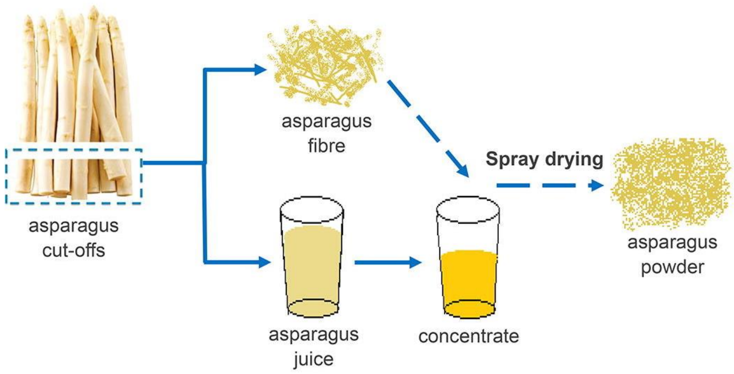

Figure 2*: Split-stream processing strategy of white asparagus waste bottom parts. Figure reproduced with permission from [4].*

Aroma analysis

The volatiles of all analysed samples were extracted from the headspace with SPME, using a PDMS/DVB/CAR (Polydimethylsiloxane/Divinylbenzene/Carboxen) fibre with 50/30 µm diameter and 1 cm length (Supelco, PA, USA). All extractions were performed by the MPS2 autosampler robot (Gerstel, the Netherlands). For the GC-MS analysis, an Agilent GC7890A coupled to a 5975C quadrupole mass spectrometer was used, and the column was a Zebron ZB-5MSplus with dimensions 30 m × 0.25 mm id × 1 µm film thickness (Phenomenex, the Netherlands). The analysis settings were as described previously [4, 5]. The GC oven temperature was programmed to start at 45 ◦C for 2 min, then increased at a rate of 8 ◦C/min to 250 ◦C, then at a rate of 15 ◦C/min to 280 ◦C and then held at 280 ◦C for 3 min. The carrier gas was helium, at a constant flow rate of 1 ml/min. The column effluent was ionised by electron impact at 70 eV, in the scan range *m*/*z* 33–330. The MS interface temperature was set to 280 ◦C. For calculating retention indices (RIs) for the identification of the compounds, a series of *n*-alkanes (C7-C21) was injected and analysed using the same method as for the samples and as part of the same sample series.

Statistical data analysis

Processed GC–MS data were subjected to Principal Component Analysis (PCA) and Hierarchical Clustering Analysis (HCA), after log10 transformation and Pareto-scaling using SIMCA 15.0.2. software (Umetrics, Sartorius Stedim Data Analytics AB, Umeå, Sweden). Additional uni- and multi-variate statistical analyses were performed using RStudio with R version 4.0.3 (2020–10-10). Graphs were also produced using Microsoft Office Excel.

Results and discussion

We aimed to investigate the influence of the carrier agent concentration used for the spray drying of asparagus concentrate on the volatiles profile of the obtained spray-dried powders, as this influenced the total solids content. Maltodextrin (MD) is a commonly-used spray drying carrier agent, and in the case of asparagus concentrate, it has been showed to lead to powders with acceptable physical properties (e.g. moisture content, particle size) [5]. In this study, we also investigated the effect of partially replacing MD by cellulose-based carriers, such as microcrystalline cellulose (MCC), citrus fibre (CF) and the AF that was pressed out of the asparagus juice during the processing. All spray-dried powder samples contained the same amount of asparagus solids to enable the direct comparison of the samples. However, the total solids content varied, and we also studied this effect. The effect of both the total solids content and the type of the cellulose-based carrier replacing MD was evident (Figure 3). The clustering of the analysed spray-dried powders is based on the carrier composition; powders with CF formed one cluster (yellow box), the AF-containing powders formed a second cluster (green box) and the powders with MD and MD + MCC formed a third cluster (black box). The grouping of the samples in the third cluster (black box) implies that there is only a minor effect of partially substituting MD with MCC. Moreover, the other two clusters suggest the potential contribution of unique compounds from CF and AF matrix to the volatile profile of the final spray-dried powders, which is expected as CF and AF are fibres from vegetables with distinct aroma profiles. In the same dendrogram, within each cluster, the powders with the same total solids content also cluster close together, implying that their profiles are similar and suggesting the impact of the total solids content on the retention of volatile components. The two powders with 30% w/w total solids content, and 10% MCC, are clustered separately and distant from all other samples (Figure 3). This deviation of the volatile profiles between the powders with 10% MCC and the rest may be linked to the fact that the MD + MCC 30–10% powders were collected from the drying chamber, instead of the collection vessel, and there the temperature is slightly higher, which can influence the volatile profile. However, this requires further investigation.

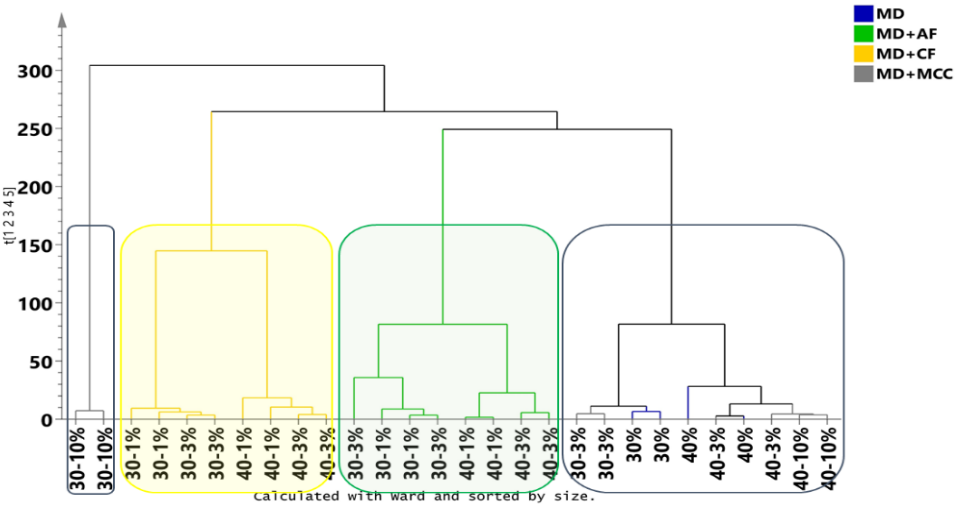

Figure 3*: Hierarchical clustering analysis on the 221 volatiles detected in 28 spray-dried asparagus powders with different carrier agents (MD: maltodextrin, MCC: microcrystalline cellulose, AF: asparagus fibre, CF: citrus fibre) and carrier concentrations (total solids content 30% or 40%). Figure reproduced with permission from [4].*

In addition, we calculated the retention of a selection of specific aroma compounds under different spray drying conditions (solids content and carrier types), on the basis of the ratio of the peak intensity in the spray-dried powder to that in the mixture before spray drying [5]. The retention of volatiles was higher in the samples with a total solids content of 40% w/w, regardless of carrier type (Figure 4). This was in agreement with the previous study where a higher MD concentration led to higher retention of important asparagus alcohols (e.g. 1-octen-3-ol) [5]. A partial replacement of MD with the cellulose-based carriers led to lower retention of the volatiles, as compared to the powders containing only MD. However, the retention of important volatiles e.g. 2-methoxy-3-isopropyl pyrazine in the AF-containing powders was ca. 80% and thus, at an acceptable level (Figure 4).

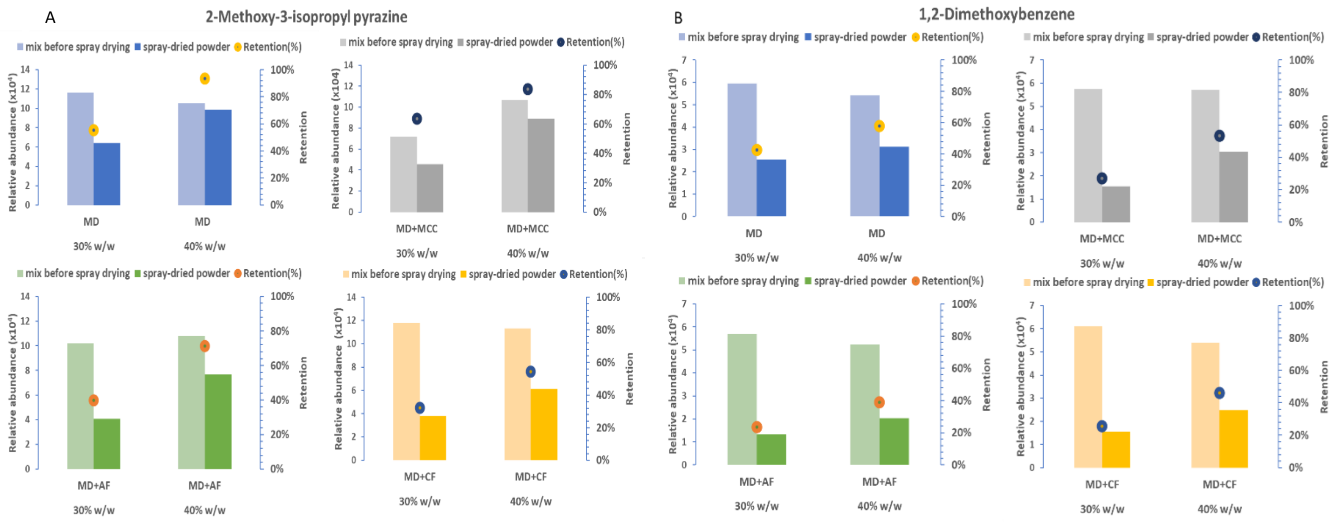

Figure 4: *Relative abundance of two selected aroma compounds in the mix before and after spray drying, and the retention% in the samples with 30 % and 40 % w/w total solids content and the different carrier agents (MD: maltodextrin, MCC: microcrystalline cellulose, AF: asparagus fibre, CF: citrus fibre). Figure reproduced with permission from [4].*

Conclusion

Asparagus waste streams can be used to produce aroma-rich spray-dried powders. Higher total solids (40% w/w) led to improved aroma retention, and in addition, low maltodextrin replacement did not strongly affect the volatile profile of the powders. Further optimization of the split-stream processing technique will lead to the effective exploitation of the asparagus waste stream to produce high-quality natural food ingredients.

Acknowledgements

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